NAVAL HEALTH RESEARCH CENTER

OCCUPATIONAL AND ENVIRONMENTAL EXPOSURE CORRELATES OF ADVERSE LIVE-BIRTH OUTCOMES AMONG 1,032 U. S. NAVY WOMEN

L. L. Hourani

S. M. Hilton

Report No. 00-09

NAVAL HEALTH RESEARCH CENTER
P O BOX 85122
SAN DIEGO, CA 92186-5122

BUREAU OF MEDICINE AND SURGERY (MED-02)
2300 E ST. NW
WASHINGTON, DC 20372-5300

OCCUPATIONAL AND ENVIRONMENTAL EXPOSURE CORRELATES OF ADVERSE LIVE-BIRTH OUTCOMES AMONG 1,032 U.S. NAVY WOMEN

Laurel Hourani, PhD, and Susan Hilton, MA

Naval Health Research Center
P.O. Box 85122
San Diego, CA 92186-5122

Report No. 00-09 supported by Bureau of Medicine and Surgery (MED-26), Washington, DC, Department of the Navy, under research work unit 65152N M00106.001-6001. The views expressed in this paper are those of the authors and do not reflect the official policy or position of the Department of the Navy, Department of Defense, or U.S. Government. Approved for public release, distribution unlimited.

The authors thank Dr. Rebecca Calderon, Dr. Frank Garland, and Messrs. Ghazi Hourani, Milan Miller, and Daniel Rahilly for many helpful contributions to this study.

ABSTRACT

The integration of women into nontraditional military occupations raises questions concerning the impact of such jobs on women's reproductive health. This study examines the extent to which US Navy women in their reproductive years report exposures to potential occupational and environmental hazards, and the degree to which such exposures are associated with self-reported adverse live-birth outcomes. Data from a survey of pregnant Navy women provided both maternal and paternal exposure information on more than 1000 active-duty women. Self-reported exposures to heavy metals, pesticides, petroleum products, and other chemicals were associated with adverse live-birth outcomes at the bivariate level. Only father's exposure to pesticides at work predicted an adverse live-birth outcome (preterm delivery) in multivariate models. Maternal occupational exposures may exert their influence through maternal health and/or pregnancy complications and act as mediators of health-reproductive outcome relationships.

The proportion of women in the US military is increasing, and the role of military women is expanding. In the US Navy, increasingly more occupational specialties and duty assignments are open to women, evidenced by the recent expansion of women's assignments to combat ships.[1] Further, the majority of active-duty women are in their peak reproductive years, with pregnancy-related hospitalizations accounting for the largest percentage (33.7%) of Navy enlisted women's hospitalizations.[2] The Navy is concerned with the impact of the corresponding exposures (physical, chemical, biological, and radiological) and experiences (ship, aviation, combat) on the health of Navy women, as well as the readiness of the Navy's medical care system to better accommodate pregnant active-duty women.

Previous studies of adverse reproductive outcomes among military women have noted increased risk of preterm labor and delivery, pregnancy-related complications, and low birthweight relative to civilian samples.[3-7] In a prior study of Navy enlisted women, elevated risks of miscarriage and ectopic pregnancy were found, and it was suggested that occupational exposure among low-ranking women may be associated with adverse reproductive outcomes.[8] A number of reproductive health hazards can be found in naval ship and/or shore commands; cadmium, mercury, lead, benzene, glycol ethers, ethylene oxide, polychlorinated biphenyls, carbon disulfide, toluene, methyl bromide, and warfarin are among the occupational reproductive stressors requiring job exposure assessment for pregnant Navy women.[9] It is unknown to what extent such potential occupational exposures in the military's non-traditional work environment are associated with adverse reproductive outcomes among Navy personnel.[10]

Both maternal and paternal exposures to environmental toxins and lifestyle habits are also associated with pregnancy outcomes. Maternal factors affecting pregnancy length/outcome include exposure to solvents,[11-13] microwave diathermy,[14] lead,[15-18] antimony, mercury, carbon disulfide, anesthetic agents,[18] ethylene oxide,[18,19] heavy lifting,[20-22] contaminated tap water,[23] caffeine,[24] alcohol,[25] and cigarette smoke.[26-28] Paternal factors negatively affecting pregnancy outcome have also been documented, including paternal exposure to lead,[16,18,19,30] mercury,[16] solvents,[31] x-rays, chloroprene, and vinyl chloride.[18] Although several studies of paternal exposures have found associations with spontaneous abortions,[16-18,31,32] little is known about the potential association of paternal exposures with adverse live-birth outcomes.

Adverse live-birth outcomes include low birthweight, preterm birth, small for gestational age, and birth defects. Low birthweight has been associated with maternal race,[33-36] smoking,[26,27] solvent exposure,[11,12] electromagnetic radiation exposure,[37] working in electronics assembly[38] or in the chemical industry,[39] strenuous work,[19] noise exposure,[40] and caffeine intake.[41] Preterm delivery or premature birth has been associated with maternal race,[42] marital status,[43] smoking,[26,27] alcohol consumption,[44] noise exposure,[40] occupational physical activity,[5,45] and number of maternal medical conditions,[43] including chorioamnion and genital tract infections.[46] A small-for-gestational-age outcome has been associated with maternal smoking,[26,27] and major birth defects have been associated with maternal solvent exposure.[11,12]

This study examined to what extent women in their reproductive years are exposed to occupational and environmental potential hazards and to what extent such exposures are associated with adverse reproductive outcomes among Navy personnel. Potential correlates of both paternal and maternal occupational and environmental exposures with adverse live-birth outcomes were examined with a case-control study design. The specific aims of this study were to (1) determine rates of selected adverse live-birth outcomes among US Navy personnel, and (2) identify occupational and environmental exposures associated with these reproductive outcomes, controlling for common confounders of exposure and reproductive outcomes identified in the literature.

Methods

Instrument and Sample

A mailed survey, referred to as the Reproductive Health (RH) Survey, requested maternal and paternal demographic, lifestyle, exposure, and pregnancy outcome information from women with a 1993 pregnancy. Targeted respondents were all pregnant Navy active-duty women who, according to hospital records, had made an inpatient or outpatient visit to the obstetrical clinic of any of 3 Navy hospitals between January and October 1993 (n = 3099). The hospitals at San Diego, CA, and Portsmouth, VA, were selected due to the large number of enlisted women at both ship and shore duty stations that report to a central obstetrical clinic (one East Coast, one West Coast). To ensure a cross-section of occupational exposures, the Jacksonville, FL, hospital was selected due to the number of enlisted women in aviation occupations within the catchment area. For 32% of the identified active-duty women, researchers were unable to obtain any address (n = 350) or any valid address (n = 643). Of the cases that were reached in the March and July 1995 mailings, 25 returned blank questionnaires declining to participate, 30 returned blank questionnaires indicating that they were not pregnant then, 862 did not respond, and 1189 responded for a response rate of 56% among reached subjects and 38% among targeted subjects. For a comparison group in initial analyses, 109 civilian dependents were also identified from hospital records of the San Diego clinic and mailed to in October 1994, and February and March 1995; 29 had a non-deliverable address, 7 declined to participate, 20 did not respond, and 53 responded (66% response rate among reached subjects, and 49% among targeted).

To assess potential nonresponse bias, questionnaire respondents and nonrespondents were compared on demographics and adverse reproductive outcomes, using information available from automated hospitalization files.

Women older than 30 years of age with a hospitalized fetal death outcome (including late deaths, ectopic pregnancies, spontaneous abortions, and other early fetal deaths, such as molar pregnancies, missed abortions, and abnormal products of conception) in the 1993 timeframe were underrepresented among the survey respondents. Therefore, only women whose 1993 pregnancy resulted in a live birth are examined in the present analyses (n=1134). Cases were included if they had none or any of five adverse live-birth outcomes (small for gestational age, birth defect, fetal distress, preterm birth, and low birthweight), leaving 1032 women in the sample, 1020 with singleton outcomes and 12 with twins.

Measures

All measures were derived from questionnaire items completed by maternal respondents. Adverse live-birth outcome variables included mother-reported baby small for gestational age, birth defect, fetal distress prior to or during delivery, preterm birth (less than 37 weeks of gestation), and low birthweight (less than 2500 g at birth). The first three measures were based on Yes/No responses to the specified terms; the fourth, preterm birth, was based on mother-reported gestation length, and low birth weight was based on mother-reported birth weight as pounds plus ounces. The main predictors and covariates of interest were duty station at pregnancy inception (ship vs shore), whether the mother or father spent any time in the Persian Gulf since around August 1990 (the start of the Gulf War), and mother-reported maternal and paternal occupational (at work) and environmental (at home) exposures (indicated by a Yes/No/Don't Know response per site per parent) during the 3 months preceding conception. These exposures included non-ionizing radiation (eg, microwaves, radio waves, video display terminal, high-voltage power lines), ionizing radiation (eg, x-rays, radioactive sources), heavy metals (eg, lead, chromium), pesticides, solvents (eg, floor paint, paint strippers, de-greasers), petroleum products (eg, jet fuel, diesel fuel), rubber-manufacturing products (eg, benzene), and other (respondent-specified) chemicals.

Control variables included demographics (race, maternal age, marital status, paygrade, parity), maternal medical history prior to the pregnancy (eg., sexually transmitted disease; underlying illness, such as hypertension or diabetes; pelvic inflammatory disease [PID]; abnormal Pap smear; drug abuse episode; blood-group incompatibility with fetus; abnormal estrogen/progesterone level; fertility treatment; tubal surgery; prescription drugs; and other reproductive complication, indicated by Yes/No responses), pregnancy complications (eg, reproductive tract infection such as chlamydia or yeast, urinary tract/bladder infection, blood infection, gestational diabetes, toxemia/pregnancy-induced hypertension, and anemia, indicated by Yes/No responses), number of pregnancy weeks before first prenatal visit; difficulty obtaining prenatal care, indicated by Yes/No response, lifestyle behaviors 3 months prior to and after pregnancy was discovered (eg, 11 ordinal categories of alcohol consumption, counts of cigarettes per day, caffeine intake indicated by counts of cups/cans/servings per day, vitamin use indicated by Yes/No, health food supplement use indicated by Yes/No), mean weight gain, months of participation in vigorous exercise at least 3 times a week, working full-time after the eighth month of pregnancy, poor nutrition, physical trauma/stress (heavy lifting, injury), and emotional stress (death of loved one, divorce, move), indicated by Yes/No. Demographic variables, except parity, were validated against available service record information, and missing data was replaced where possible.

Statistical Analysis

Univariate and bivariate analyses included rates of live-birth outcomes and chi-square tests of significance between cases, defined as women reporting at least one of the five adverse outcomes, and controls, defined as women with none of the adverse outcomes. The percentages of adverse live-birth outcomes were computed by type of exposure and selected demographic, lifestyle, and maternal health characteristics. Crude and adjusted differentials (odds ratios and 95% confidence intervals) in risk of rare (prevalence <.10) adverse outcomes were examined by exposure variables. Consistent with the guidelines of Zocchetti, et al., [47,48] for diseases with prevalence rates greater than .10, prevalence rate ratios and corresponding 95% confidence intervals were used to examine the bivariate relationships with fetal distress. Multivariate hierarchical logistic regression was used to analyze overall and exposure-specific differentials in birth outcomes. These analyses computed net differentials in outcomes between adverse outcome group and control group, by exposure and control variables. All significant control variables were entered in a first step, each was removed if it no longer contributed significantly ($P < 0.10$) to the equation, and individual exposure variables were entered in a second step in separate models to assess their unique contribution to the associated outcome.

Results

In initial analyses, active-duty women were compared with civilian dependents on key study variables. Active-duty women were significantly more likely to report exposures to petroleum products ($X^2_1 = 10.7$, $P < .002$), solvents ($X^2_1 = 30.8$, $P < .001$), and heavy metals ($X^2_1 = 5.0$, $P < .03$) at work, and to nicotine (first-/second-hand smoke, chewing tobacco, nicotine gum/patch, etc) after the pregnancy was discovered ($X^2_1 = 9.0$, $P < .003$). Compared with civilian dependents, they were also more likely to experience preterm labor during pregnancy ($X^2_1 = 4.2$, $P < .05$). Dependents did not, however, significantly differ from active-duty women on live-birth outcomes, and they were excluded from further analyses. Table 1 shows demographic profiles of the 1032 RH Survey active-duty respondents with a live birth from their 1993 pregnancy. Thirty-three percent ($n = 336$; "Cases") had at least one of the five adverse live-birth outcomes, and 67% ($n = 696$; "Controls") had none of the adverse outcomes. Demographics at estimated date of conception did not significantly differ between Cases and Controls. Overall, more than 70% were junior enlisted women less than 30 years of age. The majority of women were white, married, and had at least one previous pregnancy and live birth. Parity, dichotomized into none versus any live births among previous pregnancies, definitionally excluded those women with no previous pregnancies (41%). Parity differences were observed in the expected direction; Controls were significantly more likely than Cases to have had viable offspring among previous pregnancies.

Table 2 shows frequency distributions of the main occupational and environmental exposures.

Non-ionizing radiation was the most frequently reported exposure at both work and home for both mothers and fathers. Solvents and petroleum products were the second most frequently reported exposures in the workplace for both mothers and fathers, and pesticides and solvents were the second most frequently reported exposures at home.

Tables 3A and 3B show the distribution of adverse live-birth outcomes. One quarter of the women reported fetal distress at some time prior to or during delivery, 6% of the women reported a low birthweight or preterm baby, and 3% reported having a baby with a birth defect or that was small for its gestational age. All but 2 birth defects reported were specified. Those with minor (eg, birthmark) or invalid responses (eg, jaundice) were not included. Two percent of the respondents ($n = 15$) were missing data on at least one outcome variable and were excluded in the comorbidity analyses. As shown in Table 3B, the five singular outcomes account for 79% of occurrences among possible adverse outcome combinations. The primary comorbidities were fetal distress with birth defect (3.4%) and fetal distress with low birthweight and prematurity (3.1%).

Table 4 summarizes the significant bivariate relationships found between the reported exposure, control, and outcome variables. No outcome variables were associated with radiation, solvent, or rubber manufacturing product exposures, nor with shipboard duty (neither during pregnancy nor at estimated date of conception) or Persian Gulf duty. Of the five significant exposure variables, three occurred at work and two at home. No exposure variable was associated with fetal distress during or prior to delivery. Other variables associated with fetal distress were no live birth if previously pregnant, anemia, previous fetal death, and other prior reproductive complication. The only exposure variable related to low birthweight was maternal exposure to petroleum products at home. Low birthweight was also associated with being black, previous fetal death, multiple gestation, prior underlying illness, poor nutritional diet during pregnancy, smoking before or after pregnancy was discovered, having a reproductive tract infection, and alcohol intake before the pregnancy was discovered. Interestingly, a protective effect, similar to that found in a previous study of intrauterine growth retardation,[44] was found between any alcohol intake prior to pregnancy discovery and low birthweight. It was also noted that alcohol intake prior to pregnancy was positively related to amount of weight gain during pregnancy and that weight gain was inversely related to low birthweight. These findings require further investigation including prepregnancy body composition and nutritional/dietary factors to examine potential confounding effects. Associated with preterm birth were maternal exposure to heavy metals at work and paternal exposure to pesticides at work. Maternal age of 30 years or older was also significantly associated. Only two women reported having a blood infection during pregnancy but both had preterm babies, resulting in the observed high odds ratio. Other correlates of prematurity were multiple gestation, previous fetal death, prior PID, other prior reproductive complication, prior fertility treatment, and caffeine intake during first 6 months of pregnancy. "Other" chemical exposures, both at work and home, were significantly related to birth defects, as were at least one prior live birth if previously pregnant, multiple gestation, and prior PID. Among the "other" chemicals specified were hydraulic fluid, cleaning products, paint fumes, hospital chemicals, and automotive chemicals. None of the six exposure variables was significantly associated with reportedly small-for-gestational-age babies. However, these babies were associated with several health problems during pregnancy, including poor nutrition, reproductive tract infection, and anemia.

Table 5 shows the results of the multivariate logistic regressions. With the exception of father's exposure to pesticides at work, none of the exposure variables (all maternal) had a significant effect on adverse live-birth outcomes, after controlling for maternal demographic, lifestyle, and health variables. One exposure variable, however, showed a trend toward significance after controlling for demographic and lifestyle factors: exposure to "other" chemicals at work with birth defect ($P = .10$). Alternative modeling procedures, such as forward and backward stepwise regressions and sequential regressions forcing demographic and lifestyle variables in the equation at the first step, exposures variables at the second step, and health variables at the third step, were employed to cross-validate the models and evaluate possible mediating effects of the health variables. Results were consistent across modeling procedures, thereby supporting their general reliability.

In the final model for fetal distress prior to and/or during delivery, the main predictors were prior fetal death and prior other reproductive complication. The main predictors of low birthweight were nonwhite race, prior fetal death, multiple gestation during that pregnancy, and poor nutrition. Two separate sets of predictors emerged for prematurity. In the first model, maternal exposure to heavy metal was entered after control variables were entered; multiple gestation, blood infection during pregnancy, and prior fertility treatment predicted preterm delivery. In the second model, in which father's exposure to pesticides was entered, both prior fertility treatment and pesticide exposure were predictors of prematurity. The main predictor of a birth defect outcome was having a prior PID. Small-for-gestational-age outcomes were predicted by poor nutritional diet and having a reproductive tract infection during that pregnancy.

Discussion

In this exploratory study of the relationship of occupational and environmental hazards to adverse live-birth outcomes among Navy women, only a single exposure variable was implicated as a potential risk factor after controlling for significant covariates. Paternal, but not maternal, exposure to pesticides at work generated odds ratios of > 2 with preterm delivery. This is consistent with the association between male pesticide exposure and preterm delivery observed in the Ontario Farm Family Health Study,[49] and the lack of association found with maternal exposure to pesticides in a Southern California study.[50] Mechanisms involving animal sperm in the 3 months before conception have been described in experimental studies, but causal pathways have not yet been determined in humans.[49] Other associations observed at the bivariate level are consistent with previously published literature, in that both chemical and heavy metal exposures have been associated with increased risk for adverse birth outcomes.[30,39,51-53] However, the failure of these exposures to explain a significant proportion of the variance in birth outcomes after health variables are controlled, indicates that these exposures may exert their influence indirectly through maternal health and/or pregnancy complications. The lack of significant interaction terms further suggests that these exposures may act as mediators rather than moderators of the health-birth outcome relationships. The direct race and poor nutrition effects on reproductive outcomes in the present study have also been found with other adverse outcomes in the literature.[26,35,36,54] On the other hand, the postulated risk of potentially greater occupational physical activity and/or less opportunity for rest among pregnant military women compared with dependent or civilian women was not supported in these data. That is, by the eighth month of pregnancy, more than 45% of the sample had reduced their work schedule to part-time or had taken leave. Although these women were more likely to have reported preterm labor, they did not significantly differ from full-time workers on preterm or low-birthweight outcome.

Of interest was the lack of association between adverse live-birth outcomes and reported exposures to non-ionizing radiation, solvents, and petroleum products, the most frequently reported occupational hazards (Table 2). The ubiquity of microwave ovens and personal computers likely accounts for most of the high rate of exposure to non-ionizing radiation, with exposure rates closely matched between work and home. Exposure to solvents and petroleum products are potentially more hazardous to pregnancy outcomes than microwave oven or computer screen exposures, and the lack of associations with adverse live-birth outcomes may reflect the effectiveness of the Navy's health-oriented programs. Pro-active preventive medicine programs for occupational medicine, environmental health, and industrial hygiene specialties, for example, include new-job orientations in which potential hazards, personal protective equipment, and safety procedures are reviewed. Shipboard jobs, in particular, have Preventive Maintenance System cards posted at the job site that list equipment and materials used and protective measures that should be taken on the job. The Navy's policy of required reassignment of pregnant women to shore duty before pregnancy reaches 20 weeks[55] helps to reduce pregnant women's exposures to shipboard hazards. Individuals whose occupational exposure exceeds the Navy Occupational, Safety, and Health program's personal occupational exposure limits are enrolled in the Navy's medical surveillance program, which specializes in the diagnosis, education, treatment, and control of occupational illnesses. These programs suggest that Navy personnel are likely to know what their potential exposures are and how to avoid and/or minimize them. They also help justify confidence in the self-report of work exposures in this study, and they may explain the absence of anticipated exposure risks from specific occupational hazards and shipboard duty in general.

Also absent in the present study were observed associations between non-married marital status and emotional stress with adverse live birth outcomes sometimes found in other studies.[43,56,57] This absence may be due to methodological and/or sample differences with other studies. Such potential inconsistencies with the literature warrant further investigation.

Another objective of this study was to examine the rates of the selected birth outcomes in this sample. Evidence of higher rates of preterm delivery[3] and low birthweight for military women found in previous literature,[4,6] was not supported in the present study. However, these results are consistent with a previous study in which no differences in infant weight and gestational age were found between military and civilian women.[58] Although comparative national statistics for all outcomes are not available, Centers for Disease Control race-specific rates of low-birthweight live births are higher than the observed Navy rate (ie, 6% for US whites compared with 5% for Navy whites, and 13% for US blacks compared with 9% for Navy blacks).[59] These data are similar to those found by Buttemiller[60] in which black Air Force active-duty gravidas had only 60% the prematurity rate found for US blacks in general. Age and marital status do not appear to explain the lower Navy rates of this study. The rate of live births to Navy mothers 17 to 20 years of age (9%) was comparable to US mothers of the 18-19 age group (7%). The proportion of unmarried mothers in the Navy sample (33%) was comparable to the US in the same year (31%).[59] The Navy's selectively healthier population, aggressive occupational and environmental health programs, and readily accessible medical care coverage may help account for the Navy's overall lower rate. As evidence, prenatal care was initiated in the first trimester for 79% of US women in 1993[59] compared to 82% of Navy women in the sample.

The main strengths of this study relative to other efforts include the wide scope of both independent and dependent variables available for simultaneous evaluation, and the large sample of women with relatively homogeneous socioeconomic status and ready access to health care, which allow for more control than in other population-based studies. Several limitations are also notable. The survey did not include other potential risk factors for adverse reproductive outcomes, such as heat, cold, noise, or vibration exposures. The self-report nature of survey methods is prone to memory errors. Validation of self-reported measures including mother-reported paternal exposures was not possible in the present study. Consequently, it is feasible, for example, that the high rate of fetal distress reported may reflect respondents' unrestricted interpretation of the term; had researchers access to medical record data or had the questionnaire specified medical conditions and technical definitions associated with fetal distress (hypoxia, birth asphyxia, assisted ventilation, Apgar measures, etc), fewer respondents may have considered the condition applicable.

Sampling limitations, including potential unreported adverse outcomes, undelivered mail, and nonrandom sample selection, may also limit generalizability. Because spontaneous abortions tend to occur early in pregnancy and be underreported, a focus on live-birth outcomes avoids a potential underreporting bias[61] but it may be prone to another potential bias such as a "healthy baby effect," similar to the "healthy worker effect." That is, live births are survivors of exposure that may have led to early fetal death at high levels and congenital malformations at lower exposures. The limited number of exposure effects in the present study may be a result of observing only low exposure outcomes. Unfortunately, dosages, degrees, and routes of exposure were not determined and may well impact whether individuals are affected. Such variables will require future examination together with the other influential personal factors that have been identified in this study.

References

1. Secretary of the Navy. *Assignment of Women Members in the Department of the Navy (DON).* Philadelphia: Naval Inventory Control Point Office; 1996. SECNAVINST 1300.12B, 16 July 1996.
2. Hoiberg A, White JF. Health status of women in the armed forces. *Armed Forces and Society.* 1992;18:514-533.
3. Spandorfer SD, Graham E, Forouzan I. Pregnancy outcome in active duty seagoing women. *Mil Med.* 1996;161:214-216.
4. Fox ME, Harris RE, Brekken AL. The active-duty military pregnancy: a new high-risk category. *Am J Obstet Gynecol.* 1977;129:705-707.
5. Ramirez G, Grimes RM, Annegers JF, Davis BR, Slater CH. Occupational physical activity and other risk factors for preterm birth among US Army primigravidas. *Am J Public Health.* 1990;80:728-730.
6. Hauth JC, Gilstrap LC III, Brekken AL, Hauth JM. The effect of 17 alphahydroxy-progesterone caproate on pregnancy outcome in an active-duty military population. *Am J Obstet Gynecol.* 1983;146:187-190.
7. Magann EF, Nolan TE. Pregnancy outcome in an active-duty population. *Obstet Gynecol.* 1991;78:391-393.
8. Nice D, Hilton S. *Reproductive Outcomes in the U.S. Navy: Experience of 33,130 Hospitalized Pregnancies During 1982-1992.* San Diego, CA: Naval Health Research Center; 1997. Technical Report No. 97-16.
9. Chief of Naval Operations. *Navy Occupational Safety and Health Manual.* Washington, DC: Office of the Chief of Naval Operations; 1999:29-B-1. OPNAVINST 5100 23E, 15 January 1999, Enclosure 1, Chapter 29, Section 2903.
10. Evans MA. Generalizability in pregnancy and work research. *Mil Med.* 1998;163:304-306.
11. Hewitt JB, Tellier L. Risk of adverse outcomes in pregnant women exposed to solvents. *J Obstet Gynecol Neonatal Nurs.* 1998;27:521-531.
12. Lindbohm M. Effects of parental exposure to solvents on pregnancy outcome. *J Occup Environ Med.* 1995;37:908-914.

13. Lindbohm M, Taskinen H, Sallmen M, Hemminki K. Spontaneous abortions among women exposed to organic solvents. *Am J Ind Med.* 1990;17:449-463.

14. Ouellet-Hellstrom R, Stewart WF. Miscarriages among female physical therapists who report using radio- and microwave-frequency electromagnetic radiation. *Am J Epidemiol.* 1993;138:775-786.

15. Sallmen M, Anttila A, Lindbohm M Kyyronen P, Taskinen H, Hemminki K. Time to pregnancy among women occupationally exposed to lead. *J Occup Environ Med.* 1995;37:931-934.

16. Anttila A, Sallmen M. Effects of parental occupational exposure to lead and other metals on spontaneous abortion. *J Occup Environ Med.* 1995;37:915-921.

17. Lindbohm M, Sallmen M, Anttila A, Taskinen H, Hemminki K. Paternal occupational lead exposure and spontaneous abortion. *Scand J Work Environ Health.* 1991;17:95-103.

18. Roychowdhury M. Reproductive hazards in the work environment. *Prof Saf.* 1990;35:17-22.

19. Paul M. Occupational reproductive hazards. *Lancet.* 1997;349:1385-1388.

20. Ahlborg G. Physical work load and pregnancy outcome. *J Occup Environ Med.* 1995;37:941-944.

21. Ahlborg G Jr, Bodin L, Hogstedt C. Heavy lifting during pregnancy—a hazard to the fetus? A prospective study. *Int J Epidemiol.* 1990;19:90-97.

22. McDonald AD, Armstrong B, Cherry NM, et al. Spontaneous abortion and occupation. *J Occup Med.* 1986;28:1232-1238.

23. Hertz-Picciotto I, Swan SH, Neutra RR, Samuels SJ. Spontaneous abortions in relation to consumption of tap water: an application of methods from survival analysis to a pregnancy follow-up study. *Am J Epidemiol.* 1989;130:79-93.

24. Fenster L, Eskenazi B, Windham GC, Swan SH. Caffeine consumption during pregnancy and spontaneous abortion. *Epidemiology.* 1991;2:168-174.

25. Windham GC, Fenster L, Swan SH. Moderate maternal and paternal alcohol consumption and the risk of spontaneous abortion. *Epidemiology.* 1992;3:364-370.

26. Wu T, Buck G, Mendola P. Can regular multivitamin/mineral supplementation modify the relation between maternal smoking and select adverse birth outcomes? *Ann Epidemiol.* 1998;8:175-183.

27. Ahluwalia IB, Grummer-Strawn L, Scanlon KS. Exposure to environmental tobacco smoke and birth outcome: increased effects on pregnant women aged 30 years or older. *Am J Epidemiol.* 1997;146:42-47.

28. Ananth CV, Savitz DA, Luther ER. Maternal cigarette smoking as a risk factor for placental abruption, placenta previa, and uterine bleeding in pregnancy. *Am J Epidemiol.* 1996;144:881-889.

29. Windham GC, Swan SH, Fenster L. Parental cigarette smoking and the risk of spontaneous abortion. *Am J Epidemiol.* 1992;135:1394-1403.

30. Min YI, Correa-Villasenor A, Stewart PA. Parental occupational lead exposure and low birth weight. *Am J Ind Med.* 1996;30:569-578.

31. Lindbohm M, Hemminki K, Bonhomme MG, et al. Effects of paternal occupational exposure on spontaneous abortions. *Am J Public Health.* 1991;81:1029-1033.

32. McDonald AD, McDonald JC, Armstrong B, Cherry NM, Nolin AD, Robert D. Father's occupation and pregnancy outcome. *Br J Ind Med.* 1989;46:329-333.

33. Singh GK, Yu SM. Adverse pregnancy outcomes: differences between US- and foreign-born women in major US racial and ethnic groups. *Am J Public Health.* 1996;86:837-843.

34. National Center for Health Statistics. *Health Aspects of Pregnancy and Childbirth: United States, 1982-88.* Hyattsville, MD: Public Health Service, Washington, DC: US GPO; 1995:22. Vital and Health Statistics, Series 23, No. 18, DHHS Pub. No. PHS-95-1994.

35. Greenberg DN, Yoder BA, Clark RH, Butzin CA, Null DM. Effect of maternal race on outcome of preterm infants in the military. *Pediatrics.* 1993; 91:572-577.

36. Alexander GR, Baruffi G, Mor JM, Kieffer EC, Hulsey TC. Multiethnic variations in the pregnancy outcomes of military dependents. *Am J Public Health.* 1993;83:1721-1725.

37. Larsen AI, Olsen J, Svane O. Gender-specific reproductive outcome and exposure to high-frequency electromagnetic radiation among physiotherapists. *Scand J Work Environ Health.* 1991;17:324-329.

38. Lipscomb JA, Fenster L, Wrensch M, Shusterman D, Swan S. Pregnancy outcomes in women potentially exposed to occupational solvents and women working in the electronics industry. *J Occup Med.* 1991;33:597-604.

39. Kallen B, Landgren O. Delivery outcome in pregnancies when either parent worked in the chemical industry: a study of central registries. *J Occup Med.* 1994;36:563-568.

40. Nurminen T. Female noise exposure, shift work, and reproduction. *J Occup Environ Med.* 1995;37:945-950.

41. Santos IS, Victora CG, Huttly S, Carvalhal JB. Caffeine intake and low birth weight: a population-based case-control study. *Am J Epidemiol.* 1998;147:620-627.

42. Holzman C, Paneth N. Preterm birth: from prediction to prevention. *Am J Public Health.* 1998;88:183-184.

43. Evans MA, Rosen LN. Demographic and psychosocial risk factors for preterm delivery in an active duty pregnant population. *Mil Med.* 2000;165:49-53.

44. Lundsberg LS, Bracken MB, Saftlas AF. Low-to-moderate gestational alcohol use and intrauterine growth retardation, low birthweight, and preterm delivery. *Ann Epidemiol.* 1997;7:498-508.

45. Savitz DA, Brett KM, Dole N, Tse CJ. Male and female occupation in relation to miscarriage and preterm delivery in central North Carolina. *Ann Epidemiol.* 1997;7:509-516.

46. Gibbs RS, Romero R, Hillier SL, Eschenback DA, Sweet RL. A review of premature birth and subclinical infection. *Am J Obstet Gynecol.* 1992;166:1515-28.

47. Zocchetti C, Consonni D, Bertazzi PA. Estimation of prevalence rate ratios from cross-sectional data. *Int J Epidemiol.* 1995;24:1064-1065.

48. Zocchetti C, Consonni D, Bertazzi. Relationship between prevalence rate ratios and odds ratios in cross-sectional studies. *Int J Epidemiol.* 1997;26:220-223.

49. Savitz DA, Arbuckle T, Kaczor D, Curtis KM. Male pesticide exposure and pregnancy outcome. *Am J Epidemiol.* 1997;146:1025-1036.

50. Willis WO, Peyster A, Molgaard CA, Walker C, MacKendrick T. Pregnancy outcome among women exposed to pesticides through work or residence in an agricultural area. *J Occup Med.* 1993;35:943-949.

51. Andrews KW, Savitz DA, Hertz-Picciotto I. Prenatal lead exposure in relation to gestational age and birth weight: a review of epidemiologic studies. *Am J Ind Med.* 1994;26:13-32.

52. Huel G, Boudene C, Ibrahim MA. Cadmium and lead content of maternal and newborn hair: relationship to parity, birth weight, and hypertension. *Arch Environ Health.* 1981;36:221-227.
53. Ahlborg G, Hemminki K. Reproductive effects of chemical exposures in health professions. *J Occup Environ Med.* 1995;37:957-961.
54. Petridou E, Stoikidou M, Diamantopoulou M, Mera E, Dessypris N, Trichopoulos D. Diet during pregnancy in relation to birthweight in healthy singletons. *Child Care Health Dev.* 1998:24:229-242.
55. Chief of Naval Operations. *Management of Pregnant Servicewomen.* Washington, DC: Office of the Chief of Naval Operations; 1989:1-5.
OPNAVINST 6000.1A, 21 February 1989, Enclosure 1.
56. Homer CJ, James SA, Siegel E. Work-related psychosocial stress and risk of preterm, low birthweight delivery. *Am J Public Health.* 1990;80:173-177.
57. Lobel M. Conceptualizations, measurement, and effects of prenatal maternal stress on birth outcomes. *J Behav Med.* 1994;17:225-272.
58. Messersmith-Heroman K, Heroman WM, Moore TR. Pregnancy outcome in military and civilian women. *Mil Med.* 1994;159:577-579.
59. National Center for Health Statistics. *Health, United States, 1995.* Hyattsville, MD: Public Health Service; 1996:86-87, 90. DHHS Pub. No. PHS-96-1232.
60. Buttemiller R. Prematurity among United States Air Force active-duty gravidas. *Mil Med.* 1984;149:665-668.
61. Hemminki K, Lindbohm M, Kyyronen P. Validity aspects of exposure and outcome data in reproductive studies. *J Occup Environ Med.* 1995;37:903-907.

TABLE 1

Demographic Profile (1993) of Navy Women With Live Births

	Cases		Controls		Total	
	Number ($n = 336$)	Percent (33%)	Number ($n = 696$)	Percent (67%)	Number ($n = 1032$)	Percent (100%)
Age of mother						
17-19	32	9.5	63	9.0	95	9.2
20-24	153	45.5	334	48.0	487	47.2
25-29	86	25.6	162	23.3	248	24.0
30-34	50	14.9	109	15.7	159	15.4
35-44	15	4.5	28	4.0	43	4.2
Paygrade						
E1-E3	118	35.1	234	33.6	352	34.1
E4-E5	150	44.7	332	47.7	482	46.7
E6-E8	27	8.0	66	9.5	93	9.0
W1-O5	41	12.2	64	9.2	105	10.2
Marital status						
Married	226	68.5	455	65.8	681	66.6
Not married	104	31.5	237	34.2	341	33.4
Race/ethnic						
Non-Hispanic white	203	60.4	410	58.9	613	59.4
Non-Hispanic black	86	25.6	183	26.3	269	26.1
Hispanic/other	47	14.0	103	14.8	150	14.5
Parity*						
0	78	38.6	123	30.1	201	32.9
1+	124	61.4	286	69.9	410	67.1

Note: "Cases" had at least one of the five adverse live-birth outcomes, and "Controls" had none.

* Significant difference between cases and controls at $P < .05$.

TABLE 2

Frequencies of Occupational and Environmental Exposures by Parent and Site

	Mother						Father					
	Work		Home		Both		Work		Home		Both	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Non-ionizing radiation	544	58.1	489	50.8	425	46.4	442	56.5	459	52.5	347	45.6
Ionizing radiation	175	19.0	40	4.2	19	2.1	131	18.1	19	2.3	14	2.0
Heavy metals	95	10.7	9	1.0	7	0.8	114	16.6	12	1.5	9	1.4
Pesticides	91	10.2	136	14.8	47	5.5	83	11.8	125	15.8	41	6.0
Solvents	428	45.1	116	12.1	91	9.9	326	43.5	115	14.1	85	12.0
Petroleum products	222	23.2	54	5.6	34	3.6	236	31.0	56	6.7	39	5.4
Rubber mfg. products	33	3.7	4	0.4	2	0.2	41	6.1	5	0.6	4	0.6
Other chemicals	57	7.2	13	1.6	10	1.3	41	6.8	14	2.0	9	1.5
Shipboard duty	276	27.0	-	-	-	-	-	-	-	-	-	-
Persian Gulf	164	16.4	-	-	-	-	304	30.7	-	-	-	-

Note: differences not analyzed for statistical significance.

TABLE 3A

Rates of Adverse Outcomes of Navy Women With Live Births

Morbidity categories	Number	Percent
Fetal distress prior/during delivery	259	25.2
Low birthweight (<2500 g)	64	6.2
Preterm (<37 weeks' gestation)	61	5.9
Birth defect	33	3.2
Baby small for gestational age	31	3.0

TABLE 3B

Percentage Distribution of Comorbidities Among Women With Adverse Live-birth Outcomes

Comorbidities	**Number**	**Percent of Adverse Live Births**	**Percent of Total Live Births**
Fetal distress prior/during delivery (distress) only	204	63.6	20.1
Low birthweight (LBWT) only	15	4.7	1.5
Preterm only	21	6.5	2.1
Birth defect (defect) only	13	4.0	1.3
Baby small for gestational age (small) only	1	0.3	0.1
Distress and LBWT	1	0.3	0.1
Distress and preterm	3	0.9	0.3
Distress and defect	11	3.4	1.1
Distress and small	5	1.6	0.5
LBWT and preterm	8	2.5	0.8
LBWT and defect	1	0.3	0.1
LBWT and small	6	1.9	0.6
Preterm and defect	1	0.3	0.1
Preterm and small	1	0.3	0.1
Defect and small	0	0	0
Distress and LWBT and preterm	10	3.1	1.0
Distress and LBWT and defect	1	0.3	0.1
Distress and LBWT and small	5	1.6	0.5
Distress and preterm and defect	0	0	0
Distress and preterm and small	0	0	0
Distress and defect and small	0	0	0
LBWT and preterm and defect	0	0	0
LBWT and preterm and small	4	1.2	0.4
LBWT and defect and small	0	0	0
Preterm and defect and small	0	0	0
Distress and LBWT and preterm and defect	1	0.3	0.1
Distress and LBWT and preterm and small	6	1.9	0.6
Distress and LBWT and defect and small	2	0.6	0.2
Distress and preterm and defect and small	0	0	0
LBWT and preterm and defect and small	0	0	0
Distress and LBWT and preterm and defect and small	1	0.3	0.1

REPORT DOCUMENTATION PAGE

Form Approval
OMD No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE July 1999

3. REPORT TYPE AND DATE COVERED Final 10/98 to 6/99

4. TITLE AND SUBTITLE Occupational and Environmental Exposure Correlates of Adverse Live-Birth Outcomes Among US Navy Women

5. FUNDING NUMBERS
Program Element: 65152N
Work Unit Number: M00106.001-6001

6. AUTHOR(S) Laurel Hourani, Ph.D., and Susan Hilton, M.A.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Health Research Center
PO Box 85122
San Diego, CA 92186-5122

8. PERFORMING ORGANIZATION Report No. 00-09

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of Naval Research
800 North Quincy Street
Arlington, VA 22217-5660

Bureau of Medicine and Surgery (MED-26)
Department of the Navy
2300 E Street, NW
Washington, DC 20372-5300

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE
A

13. ABSTRACT *(Maximum 200 words)*

The integration of women into nontraditional military occupations raises questions concerning the impact of such jobs on women's reproductive health. This study examined to what extent women in their reproductive years report exposures to occupational and environmental potential hazards and to what extent such exposures were associated with adverse live-birth outcomes among Navy personnel. Data from a survey of pregnant Navy women provided both maternal and paternal exposure information on more than 1 000 active-duty women. Self-reported exposures to heavy metals, pesticides, petroleum products, and other chemicals were associated with adverse outcomes at the bivariate level. Only father's exposure to pesticides at work predicted premature delivery in multivariate models. Maternal occupational exposures may exert their influence through maternal health and/or pregnancy complications and may act as mediators rather than moderators of health-birth outcome relationships.

14. SUBJECT TERMS Reproductive health, pregnancy complications, Navy active-duty women, occupational exposures, environmental exposures

15. NUMBER OF PAGES 24

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z-39-18 298-102